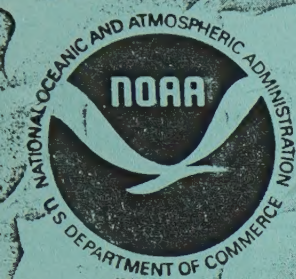


85-08



SOUTHWEST FISHERIES CENTER

P.O. BOX 271

LA JOLLA, CA 92038

NATIONAL MARINE FISHERIES SERVICE

SOUTHWEST FISHERIES CENTER

MARCH 1985

A TEST FOR DETERMINING EXTINCTION
TIMES WITH PRACTICAL APPLICATIONS

By

JAMES M. BERKSON, DOUGLAS P. DEMASTER
AND DANIEL GOODMAN

Library
NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

ADMINISTRATIVE REPORT LJ-85-08

This report is used to insure prompt dissemination of preliminary results, interim reports, and special studies to the scientific community. The material is not ready for formal publication since the paper may later be published in a modified form to include more recent information or research results. Abstracting, citing, or reproduction of this information is not allowed. Contact author if additional information is required.

RECEIVED
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 20540
JAN 10 1964

A TEST FOR DETERMINING EXTINCTION TIMES

WITH PRACTICAL APPLICATIONS

By

James M. Berkson
Southwest Fisheries Center
P.O. Box 271
La Jolla, California 92038

Dr. Douglas P. DeMaster
Southwest Fisheries Center*
P.O. Box 271
La Jolla, California 92038

Dr. Daniel Goodman
Biology Department
Montana State University
Bozeman, Montana 59717

CONTENTS

ABSTRACT	1
INTRODUCTION	1
METHODS	2
General Model	2
Specific Model	5
RESULTS	6
DISCUSSION	6
LITERATURE CITED	8

LIST OF TABLES

Table 1	Growth rates and variances for various pinniped populations ..	9
Table 2	Mean extinction time results, given for different levels of r and three levels of $V(env)$	10

LIST OF FIGURES

Figure 1	Relationship among mean persistence time, initial population size, and growth rate. Analyses assume: $K=1000$ and $V(env)=0.0929$	11
----------	---	----

A test for determining mean extinction times
with practical applications.

James M. Berkson, Douglas P. DeMaster, Daniel Goodman

ABSTRACT

In this paper, a stochastic model is used to calculate mean persistence times for populations given an estimated growth rate and an estimated variance around the growth rate. Increasing growth rates and/or initial population size increases time until extinction as does decreasing variability around the mean growth rate.

INTRODUCTION

The primary goal in managing endangered species is preservation of the species. This is a goal few would argue with but it is rather vague to implement, because a time scale must be specified. Do we manage in order to reserve the species for the next generation, the next century, or the next year? In order for any such criterion to be met, managers must be able to test management strategies on the expected survival time, or persistence time, of the species.

Predicting the persistence times of a species under different management strategies is difficult. Little actual data have been collected on the subject. Most of the work on the topic has involved modeling of one form or another. Most of these models involve many parameters in order to be made operational. In particular, they require knowledge of the life history parameters of the species in question, as well as knowledge of how

stochasticity affects these life history parameters (Nichols et al. 1980, Simons 1984). This kind of information has been difficult to gather even with large populations of well-known and easily studied mammals. It is even more difficult, if not impossible, to obtain information of this kind on endangered species populations due to their small numbers and the time it would require to gather enough data.

A different type of model has been suggested by Goodman (1984). This model is essentially a modification of the birth-death process model (Feller 1939). It requires only a series of observed population estimates in order to calculate mean extinction times. For management wishing to preserve species in their trust, this model provides a way to estimate a species' persistence times under various management strategies.

METHODS

General Model

Using the birth-death process model, a solution for mean extinction time is the following:

$$t = \sum_{m=1}^n \sum_{i=m}^K \frac{1}{i \cdot u(i)} \sum_{j=m}^{i-1} \frac{b(j)}{u(j)}$$

where: $t(n)$ = mean extinction time

n = initial population size

K = carrying capacity

$b(j)$ = birth rate for population at size j

$u(j)$ = death rate for population at size j

Birth and death rates are calculated using equations presented in Goodman (1984). These equations are of the form:

$$u(n) = \frac{n \text{ Var}[r(n)] - E[r(n)]}{2}$$

$$b(n) = E[r(n)] + u(n)$$

where: $E[r(n)]$ = expected growth rate

$\text{Var}[r(n)]$ = variance in growth rate

The variance is further defined as consisting of two parts, an environmental component and an individual component. The total variance is calculated by:

$$\text{Var}[r(n)] = \frac{V_I}{n} + V(\text{env})$$

where: V_I = individual variance

$V(\text{env})$ = environmental variance

Environmental variance affects the entire population. Examples are weather changes, predation, etc. Individual variance acts independently on each member of the population. Examples are the chance element of sex determination or accidental death (Goodman 1984).

The parameters to be estimated for use in the model are: $E[r]$, V_I , and $V(\text{env})$. N and k are management decision parameters that can be manipulated to determine a range of persistence times.

In order to estimate $E[r]$, it is necessary to have a time series of population census data.

$$\text{Lambda}(t) = \frac{n(t)}{n(t-1)}$$

$$r(t) = \ln(\text{Lambda}(t))$$

$$E[r] = \frac{\sum_{i=1}^x r(i)}{x}$$

where: x = the number of growth rate estimates in the sample.

Estimating the variance is slightly more difficult. Basically, we have assumed that there are two independent sources of variation: individual and environmental. Individual variance is important only when populations are at extremely low levels (Goodman 1984). Therefore, any variance found in the estimates of r for populations not at extremely low levels will be caused for the most part by environmental variance. $V(\text{env})$ can be estimated using the same time series of census data used to estimate $E(r)$, for populations above some minimal level.

$$V(\text{env}) = \frac{\sum_{i=1}^x [r(i) - E(r)]^2}{x - 1}$$

In order to obtain an estimate for individual variance, we need to look at the most important factors contributing to it. Four main factors contribute to individual variance: differences in sex ratios of offspring, the mortality process as a chance mechanism, the chance component of reproduction, and effects of a varying age structure (Goodman, pers. comm.). Insufficient work has been done on this topic to enable the estimation of individual variance. For this first working paper, the value

of 0.45 was arbitrarily selected for V_1 . This represents a level of individual variance that contributes very little to the total variance with population levels above 100 individuals. Unfortunately, before a population can go extinct, it must fall to levels below 100. Therefore, data on this parameter are necessary in the actual application of this analysis. Obviously, more work is needed to obtain a reliable estimate.

Specific Model

In order to test this model, we looked at a sample of pinniped populations for which annual counts have been reported (see Table 1 for references). These counts were in the form of pup counts. It is true that biases exist in pinniped pup counts (Berkson and DeMaster 1984), but they were ignored for our exercise. In addition, we assumed that none of the variance in the pup counts was due to measurement error; therefore, population growth rates and the associated variance can be estimated from pup counts. As a worst case, the variance in pup counts reflects the variance in annual birth rates and only a portion of the variance in death rates. If we assume the variance due to deaths is not greater than the variance due to births, the "worst-case" total variance can be estimated by doubling the variance from the pup counts (Table 1).

The estimate of individual variance of 0.45 was used in all runs of our model. Three of the estimated environmental variances were tested, one high, one low, and one in between. K was chosen to be 1000 individuals to allow a reasonable computation time by our computer system. A range of initial population sizes from one to K was used to calculate the mean persistence time.

RESULTS

The results show several trends. First, as environmental variance increases, extinction time decreases. Second as the expected growth rate increases, extinction time increases. Third, the spread of extinction times between low variance and high variance increases as the growth rate increases. Fourth, as initial population size increases, extinction time increases. This relationship takes the form of a saturation curve (Figure 1). Finally, for positive growth rates, low variances cause the population to reach the asymptote more quickly than high variances (Table 2).

DISCUSSION

In our pinniped example, we looked at a wide range of reported environmental variances to calculate extinction times. In practice, the range of environmental variances would in many cases be smaller, so the extinction time would also be smaller.

With smaller ranges of extinction time estimates available, managers can test different management strategies to determine their effect on persistence time. Keeping the population at a higher percentage of K would in turn increase the time until extinction. Increasing survival rates and/or fecundity rates of the species would result in increased growth rate and increased extinction time. Decreasing the variance around the growth rate would also increase the extinction time.

Future work on this model will include determining the distribution of extinction times for any given set of parameters to enable the formation of confidence intervals. This is necessary because it may not be acceptable to manage on the basis of mean persistence times. Rather, some type of game theory, where losses are minimized, needs to be applied to this problem. Unfortunately, this approach requires information concerning the shape of the distribution of mean persistence times.

LITERATURE CITED

- BERKSON, J.M., and D.P. DeMASTER. Use of pup counts in indexing population changes in pinnipeds. *Can J. of Fish. and Aqua. Sci.* (in press).
- BOVENG, P. 1983. A dyanmic response estimation of the status of Northern elephant seal populations, relative to the maximum net productivity level. 23 pages.
- DEMASTER, D.P., D.J. MILLER, D. GOODMAN, R.L. DeLONG, and B.S. STEWART. 1982. Assessment of California sea lion fishery interactions. Transactions of the 47th N. American Wildlife and Natural Resources Conference. 47:253-264.
- EBERHARDT, L.L. 1981. Population Dynamics of the Pribilof fur seals. pp. 197-220. *In*: C.W. Fowler and T.D. Smith, (eds.), Dynamics of large mammal populations. John Wiley and Sons, New York, NY, USA.
- FELLER, W. 1939. Die Grundlagen der Volterraschen Thoerie des Kampfes ums dasein in wahrscheinlichkeitstheoretischer behandlung. *Acta Biotheoretica* 5:11-40.
- GOODMAN, D. 1984. The minimum viable population problem, I. The demography of chance extinction. SWFC Admin. Report LJ-84-44c. 38 pp.
- KOZLOFF P. (ed.) 1982. Fur seal Investigations, 1981. NOAA Technical Memorandum NMFS F/NWC-37. National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA., USA. 88 pages.
- NICHOLS, J.D., G.L. HENSLEY, and P.W. SYKES, JR. 1980. Demography of the everglade kite: Implications for population management. *Ecological Modeling* 9:215-232.
- SIMONS, T.R. 1984. A population model of the endangered Hawaiian dark-rumped petrel. *J. Wild. Man.* 48(4):1065-1076.
- SMITH, T.D., and T. POLACHECK. 1984. The population dynamics of the Alaska fur seal: What do we really know? NWAFC Processed Report 84-15. Northwest and Alaska Fisheries Center. National Marine Fisheries Service. USA. 122 pages.

Table 1. Growth rates and variances for various pinniped populations.

Species	Years	# Points	E(r)	Var[E(r)]
Alaska fur seal (<u>Callorhinus ursinus</u>) (Smith and Polacheck 1984) (St. Paul Island)	13-22	10	.09	.0043
Pribilof fur seal (females only) (<u>Callorhinus ursinus</u>) (Eberhardt 1981) (St. Paul Island)	50-65	15	-.03	.0046
Northern elephant seal (<u>Mirounga angustirostris</u>) (Boveng 1983) (Ano Nuevo Island)	67-80	13	.17	.0060
Northern elephant seal (<u>Mirounga angustirostris</u>) (Boveng 1983) (San Miguel Island)	75-82	7	.11	.0103
Alaska fur seal (<u>Callorhinus ursinus</u>) (Smith and Polacheck 1984) (St. Paul Island)	61-76	13	-.02	.0109
California sea lion (<u>Zalophus californianus</u>) (DeMaster et.al. 1982) (San Miguel Island)	69-81	7	-.02	.0332
Northern fur seal (<u>Callorhinus ursinus</u>) (Kozloff 1981, DeLong pers. comm.) (Adam's Cove, San Miguel Island)	74-84	10	.15	.1198

Table 2. Mean extinction time results

K = 1000					
N	V(env)	E(r)=			
		-.05	.00	.05	.10
1	.0086	7.88	19.9	2.67 E+13	1.78 E+28
	.0665	6.89	11.4	105.	42400.
	.2395	5.00	6.44	9.38	17.9
5	.0086	22.0	72.1	9.09 E+13	4.47 E+28
	.0665	18.2	33.4	365.	1.17 E+ 5
	.2395	12.0	15.9	24.0	47.4
10	.0086	31.0	117.	1.23 E+14	5.02 E+28
	.0665	24.9	47.8	537.	1.47 E+ 5
	.2395	15.7	20.9	32.0	63.2
20	.0086	41.3	182.	1.42 E+14	5.12 E+28
	.0665	32.2	64.5	714.	1.64 E+ 5
	.2395	19.5	26.3	40.4	79.0
50	.0086	56.4	301.	1.46 E+14	5.12 E+28
	.0665	42.6	88.5	908.	1.72 E+ 5
	.2395	24.6	33.4	51.3	98.1
100	.0086	68.5	411.	1.46 E+14	5.12 E+28
	.0665	50.6	107.	1010.	1.73 E+ 5
	.2395	28.5	38.6	58.9	110.
250	.0086	85.0	564.	1.46 E+14	5.12 E+28
	.0665	61.0	129.	1090.	1.73 E+ 5
	.2395	33.1	44.8	67.7	122.
500	.0086	97.5	663.	1.46 E+14	5.12 E+28
	.0665	68.3	142.	1110.	1.73 E+ 5
	.2395	35.7	48.1	72.4	128.
750	.0086	105.	702.	1.46 E+14	5.12 E+28
	.0665	71.9	147.	1110.	1.73 E+ 5
	.2395	36.4	49.0	73.5	130.
1000	.0086	108.	712.	1.46 E+14	5.12 E+28
	.0665	72.9	148.	1110.	1.73 E+ 5
	.2395	36.4	49.0	73.5	130.

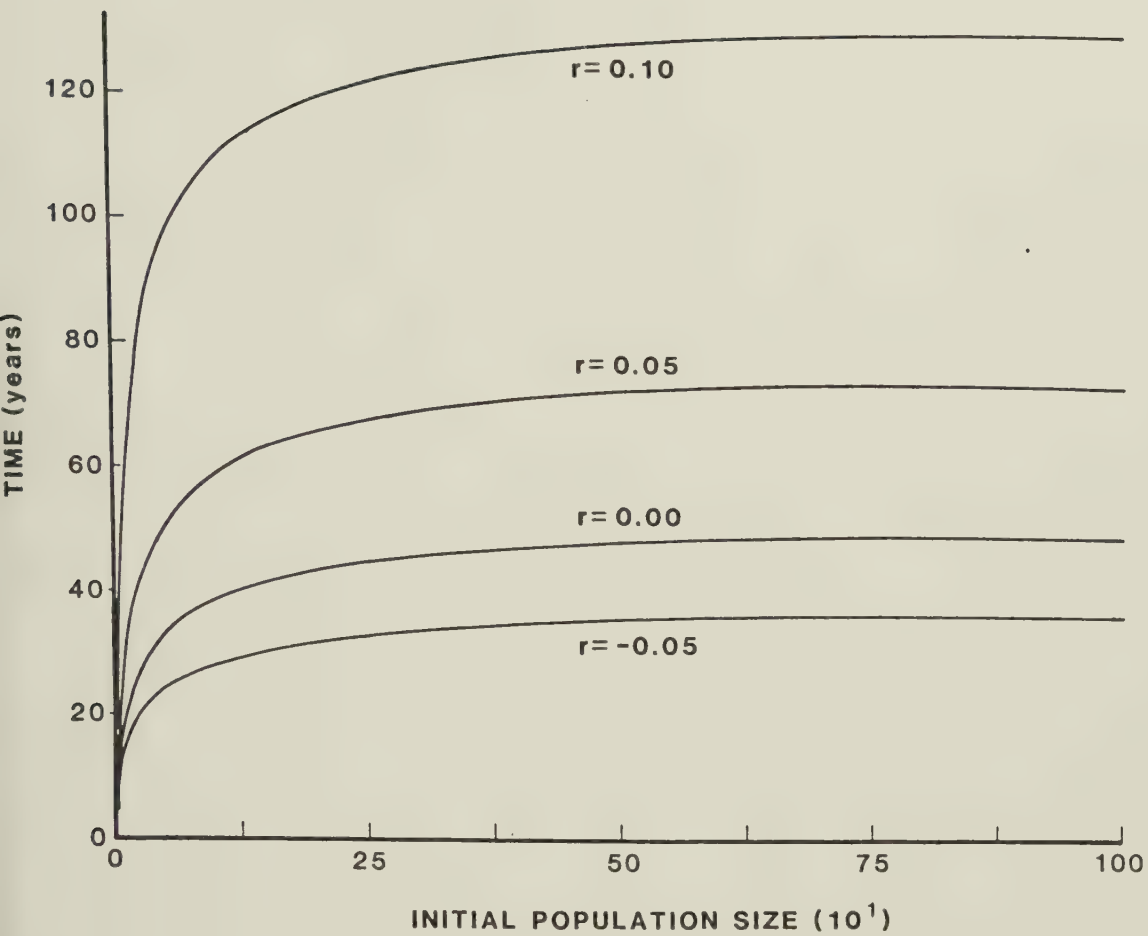


Figure 1 Relationship among mean persistence time, initial population size, and growth rate. Analyses assume: $K=1000$ and $V(env)=0.0929$

